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2.5D true-amplitude Kirchhoff migration and demigration

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ABSTRACT

Kirchhoff-type migration and demigration for three dimensions are exceedingly expensive processes in laterally inhomogeneous media due to the intense numerics required. For simpler types of media, however, the formulas to be implemented simplify considerably. For 3D in-plane wave propagation in 2D media, i.e., the 2.5D situation, 2D ray tracing is sufficient for full 3D true-amplitude migration or demigration. In 1D media, both imaging operations require the solution of certain integrals of a semi-analytic character which can be implemented in an even cheaper way. For some specific velocity distributions (such as constant velocity, constant velocity gradient, constant gradient of quadratic slowness and constant gradient of logarithmic velocity) fully analytic expressions can be derived. If the velocity distribution in the true earth model can be reasonably well represented by one of the considered situations, a very fast approximate true-amplitude Kirchhoff-type migration can be performed. Moreover, simple models in which the algorithms perform fast and accurately can be of great value for (a) validating the algorithms so as to ensure correct results in the desired realistic situations and (b) gaining insight on how to interpret the results.

INTRODUCTION

Kirchhoff-type migration (Schneider, 1978; Bleistein, 1987; Schleicher et al., 1993) and demigration are not only two of the most important tools in seismic imaging with a broad range of practical applications but also form the basis for the derivation of many other imaging operations (Tygel et al., 1996). Although full 3D Kirchhoff-type migration and demigration become more and more feasible in practice due to the developments in modern computer technology, they are still quite expensive methods to perform. This fact motivated us to study Kirchhoff-type migration and demigration for simpler types of media in order to provide cheaper and faster although maybe less accurate alternatives.

Following the lines of Bleistein (1986), we derive the corresponding representations

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for the true-amplitude migration and demigration integrals in two-and-one-half dimensions, i.e., considering 3D wave propagation in a medium that does not vary in the horizontal direction perpendicular to the seismic line. The stack involved in Kirchhoff-type methods needs to be performed over a 2D data slice instead of a 3D data volume, and also the necessary Green's functions can then be computed using 2D instead of 3D dynamic ray tracing.

For the case of a purely vertically inhomogeneous medium, the resulting formulas can be further simplified such that instead of 2D dynamic ray tracing for the computation of the Green's functions, only the solution of some simple integrals along the ray paths is necessary.

For four basic vertical velocity distributions (constant velocity, constant gradient velocity, constant gradient of quadratic velocity and constant gradient of logarithmic velocity), analytic formulas for the stacking lines migration and weight functions for Kirchhoff-type migration and demigration can be found. For these velocity distributions – and for any true distribution that can be reasonably well approximated by one of them – Green's functions computations are no longer necessary and thus, an efficient true-amplitude migration or demigration becomes possible.

CONCLUSION

Kirchhoff-type migration and demigration are not only two of the most important tools in seismic imaging with a broad range of practical applications but also form the basis for the derivation of many other imaging operations (Tygel et al., 1996). When applied to 3D complex geological structures, both operations can become exceedingly expensive. For the purpose of a more efficient application of these tools in the seismic practice, we have derived the corresponding representations for the true-amplitude Kirchhoff-type migration and demigration integrals in two-and-one-half dimensions, i.e., considering 3D wave propagation in a medium that does not vary in the horizontal direction perpendicular to the seismic line. Applying the stationary phase method to the out-of-plane integral of the full 3D representation using the medium particularities (Bleistein, 1986; Bleistein et al., 1987), we have shown that in this situation a 2D operation is sufficient to perform a Kirchhoff-type migration or demigration including a full 3D geometrical-spreading correction. To compute the corresponding stacking lines and weight functions, only 2D instead of full 3D dynamic ray tracing is required in the macro velocity model supposed to be known. If the medium depends on the depth coordinate only, dynamic ray tracing can be replaced by the numerical solution of some simple integrals along the ray paths. For four basic vertical velocity distributions (constant velocity, constant gradient of velocity, constant gradient of quadratic slowness, and constant gradient of logarithmic velocity), analytic formulas for the stacking lines and weight functions have been derived and numerically compared. If the velocity distribution in the true 3D earth model can be reasonably well represented by one of the considered cases, a very fast approximate true-amplitude Kirchhoff-type migration or demigration within 2D data slice can be performed using the analytic or semi-analytic expressions instead of a full 3D true-amplitude migration.

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PUBLICATIONS

Detailed results were presented at the Karlsruhe Workshop on Amplitude-Preserving Seismic Reflection Imaging and published in the Special Issue of Journal of Seismic Exploration. (Martins et al., 1997).

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